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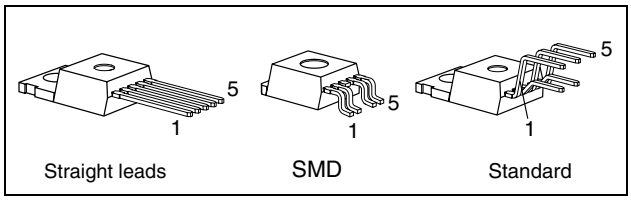
Smart Highside Power Switch

Features

- Load dump and reverse battery protection[1)]
- Clamp of negative voltage at output
- Short-circuit protection
- Current limitation
- Thermal shutdown
- Diagnostic feedback
- Open load detection in ON-state
- CMOS compatible input
- **E**lectro**s**tatic **d**ischarge (**ESD**) protection
- Loss of ground and loss of V_{bb} protection[2)]
- Overvoltage protection
- Undervoltage and overvoltage shutdown with auto-restart and hysteresis

Product Summary

$V_{Load\ dump}$	80	V
V_{bb}-V_{OUT} Avalanche Clamp	58	V
V_{bb} (operation)	4.5 ... 42	V
V_{bb} (reverse)	-32	V
R_{ON}	38	mΩ
$I_{L(SCp)}$	21	A
$I_{L(SCr)}$	10	A
$I_{L(ISO)}$	11	A

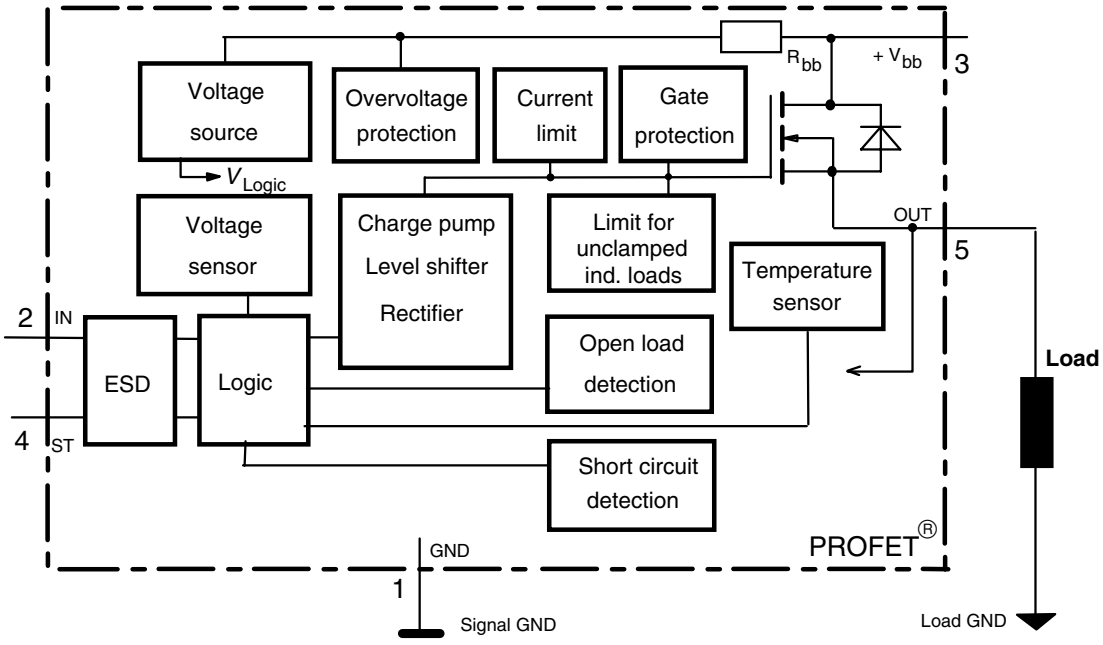


Application

- µC compatible power switch with diagnostic feedback for 12 V and 24 V DC grounded loads
- Most suitable for inductive loads
- Replaces electromechanical relays and discrete circuits

General Description

N channel vertical power FET with charge pump, ground referenced CMOS compatible input and diagnostic feedback, integrated in Smart SIPMOS® chip on chip technology. Fully protected by embedded protection functions.



1) No external components required, reverse load current limited by connected load.
2) Additional external diode required for charged inductive loads

Pin	Symbol		Function
1	GND	-	Logic ground
2	IN	I	Input, activates the power switch in case of logical high signal
3	Vbb	+	Positive power supply voltage, the tab is shorted to this pin
4	ST	S	Diagnostic feedback, low on failure
5	OUT (Load, L)	O	Output to the load

Maximum Ratings at T_j = 25 °C unless otherwise specified

Parameter	Symbol	Values	Unit
Supply voltage (overvoltage protection see page 3)	V_{bb}	63	V
Load dump protection $V_{LoadDump} = U_A + V_s$, U_A = 13.5 V R_I= 2 Ω, R_L= 1.1 Ω, t_d= 200 ms, IN= low or high	V_s[3)]	66.5	V
Load current (Short-circuit current, see page 4)	I_L	self-limited	A
Operating temperature range	T_j	-40 ...+150	°C
Storage temperature range	T_{stg}	-55 ...+150	
Power dissipation (DC)	P_{tot}	125	W
Inductive load switch-off energy dissipation, single pulse T_j=150 °C:	E_{AS}	1.7	J
Electrostatic discharge capability (ESD) (Human Body Model)	V_{ESD}	2.0	kV
Input voltage (DC)	V_{IN}	-0.5 ... +6	V
Current through input pin (DC)	I_{IN}	±5.0	mA
Current through status pin (DC) see internal circuit diagrams page 6...	I_{ST}	±5.0	

Thermal resistance chip - case:	R_{thJC}	≤ 1	K/W
junction - ambient (free air):	R_{thJA}	≤ 75	
SMD version, device on pcb[4)]:		≤ tbd	

3) V_S is setup without DUT connected to the generator per ISO 7637-1 and DIN 40839

4) Device on 50mm*50mm*1.5mm epoxy PCB FR4 with 6cm² (one layer, 70µm thick) copper area for V_{bb} connection. PCB is vertical without blown air.

Electrical Characteristics

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Load Switching Capabilities and Characteristics					
On-state resistance (pin 3 to 5)					
I_L = 2 A T_j=25 °C:	R_{ON}	--	30	38	mΩ
T_j=150 °C:			55	70	
Nominal load current (pin 3 to 5) ISO Proposal: V_{ON} = 0.5 V, T_C = 85 °C	$I_{L(ISO)}$	9	11	--	A
Output current (pin 5) while GND disconnected or GND pulled up, V_{IN}= 0, see diagram page 7, T_j =-40...+150°C	$I_{L(GNDhigh)}$	--	--	1	mA
Turn-on time to 90% V_{OUT}:	t_{on}	50	160	300	µs
Turn-off time to 10% V_{OUT}:	t_{off}	10	--	80	
R_L = 12 Ω, T_j =-40...+150°C					
Slew rate on 10 to 30% V_{OUT}, R_L = 12 Ω, T_j =-40...+150°C	dV/dt_{on}	0.4	--	2.5	V/µs
Slew rate off 70 to 40% V_{OUT}, R_L = 12 Ω, T_j =-40...+150°C	$-dV/dt_{off}$	1	--	5	V/µs
Operating Parameters					
Operating voltage [5] T_j =-40...+150°C:	$V_{bb(on)}$	4.5	--	42	V
Undervoltage shutdown T_j =-40...+150°C:	$V_{bb(under)}$	2.4	--	4.5	V
Undervoltage restart T_j =-40...+150°C:	$V_{bb(u\ rst)}$	--	--	4.5	V
Undervoltage restart of charge pump see diagram page 12 T_j =-40...+150°C:	$V_{bb(ucp)}$	--	6.5	7.5	V
Undervoltage hysteresis $\Delta V_{bb(under)} = V_{bb(u\ rst)} - V_{bb(under)}$	$\Delta V_{bb(under)}$	--	0.2	--	V
Overvoltage shutdown T_j =-40...+150°C:	$V_{bb(over)}$	42	--	52	V
Overvoltage restart T_j =-40...+150°C:	$V_{bb(o\ rst)}$	42	--	--	V
Overvoltage hysteresis T_j =-40...+150°C:	$\Delta V_{bb(over)}$	--	0.2	--	V
Overvoltage protection[6] T_j =-40°C:	$V_{bb(AZ)}$	60	--	--	V
I_{bb}=40 mA T_j =25...+150°C:		63	67		
Standby current (pin 3) T_j=-40...+25°C:	$I_{bb(off)}$	--	12	25	µA
V_{IN}=0 T_j=150°C:		--	18	60	
Leakage output current (included in $I_{bb(off)}$) V_{IN}=0	$I_{L(off)}$	--	6	--	µA
Operating current (Pin 1)[7], V_{IN}=5 V	I_{GND}	--	1.1	--	mA

5) At supply voltage increase up to V_{bb}= 6.5 V typ without charge pump, $V_{OUT} \approx V_{bb}$ - 2 V

6) see also $V_{ON(CL)}$ in table of protection functions and circuit diagram page 7. Meassured without load.

7) Add I_{ST}, if I_{ST} > 0, add I_{IN}, if V_{IN}>5.5 V

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Protection Functions					
Initial peak short circuit current limit (pin 3 to 5)[8], (max 400 µs if $V_{ON} > V_{ON(SC)}$)	$I_{L(SCp)}$				
T_j =-40°C:		--	--	35	A
T_j =25°C:		--	21	--	
T_j =+150°C:		7	--	--	
Repetitive short circuit current limit $T_j = T_{jt}$ (see timing diagrams, page 10)	$I_{L(SCr)}$	6	10	--	A
Short circuit shutdown delay after input pos. slope $V_{ON} > V_{ON(SC)}$, T_j =-40..+150°C: min value valid only, if input "low" time exceeds 30 µs	$t_{d(SC)}$	80	--	400	µs
Output clamp (inductive load switch off) at $V_{OUT} = V_{bb} - V_{ON(CL)}$, I_L= 30 mA	$V_{ON(CL)}$	--	58	--	V
Short circuit shutdown detection voltage (pin 3 to 5)	$V_{ON(SC)}$	--	8.3	--	V
Thermal overload trip temperature	T_{jt}	150	--	--	°C
Thermal hysteresis	ΔT_{jt}	--	10	--	K
Inductive load switch-off energy dissipation[9], $T_{j\,Start}$ = 150 °C, single pulse V_{bb} = 12 V:	E_{AS} E_{Load12}	--	--	1.7 1.3	J
V_{bb} = 24 V:	E_{Load24}			1.0	
Reverse battery (pin 3 to 1) [10]	$-V_{bb}$	--	--	32	V
Integrated resistor in V_{bb} line	R_{bb}	--	120	--	Ω
Diagnostic Characteristics					
Open load detection current T_j=-40 °C: (on-condition) T_j=25..150°C:	$I_{L\,(OL)}$	2 2	-- --	900 750	mA

8) Short circuit current limit for max. duration of 400 µs, prior to shutdown (see $t_{d(SC)}$ page 4)

9) While demagnetizing load inductance, dissipated energy in PROFET is $E_{AS} = \int V_{ON(CL)} * i_L(t)\,dt$, approx. $E_{AS} = {}^1/_2 * L * I_L^2 * \left(\frac{V_{ON(CL)}}{V_{ON(CL)} - V_{bb}}\right)$, see diagram page 8

10) Reverse load current (through intrinsic drain-source diode) is normally limited by the connected load. Reverse current I_{GND} of ≈ 0.3 A at V_{bb}= -32 V through the logic heats up the device. Time allowed under these condition is dependent on the size of the heatsink. Reverse I_{GND} can be reduced by an additional external GND-resistor (150 Ω). Input and Status currents have to be limited (see max. ratings page 2 and circuit page 7).

Parameter and Conditions at T_j = 25 °C, V_{bb} = 12 V unless otherwise specified	Symbol	Values			Unit
		min	typ	max	
Input and Status Feedback[11)]					
Input turn-on threshold voltage ⎍ T_j =-40..+150°C:	$V_{IN(T+)}$	1.5	--	2.4	V
Input turn-off threshold voltage ⎎ T_j =-40..+150°C:	$V_{IN(T-)}$	1.0	--	--	V
Input threshold hysteresis	$\Delta V_{IN(T)}$	--	0.5	--	V
Off state input current (pin 2) V_{IN} = 0.4 V:	$I_{IN(off)}$	1	--	30	µA
On state input current (pin 2) V_{IN} = 3.5 V:	$I_{IN(on)}$	10	25	50	µA
Status invalid after positive input slope (short circuit) T_j=-40 ... +150°C:	$t_{d(ST\ SC)}$	80	200	400	µs
Status invalid after positive input slope (open load) T_j=-40 ... +150°C:	$t_{d(ST)}$	350	--	1600	µs
Status output (open drain)					
Zener limit voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(high)}$	5.4	6.1	--	V
ST low voltage T_j =-40...+150°C, I_{ST} = +1.6 mA:	$V_{ST(low)}$	--	--	0.4	

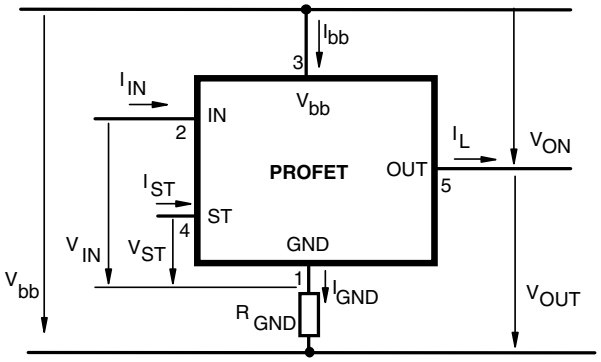
11) If a ground resistor R_{GND} is used, add the voltage drop across this resistor.

Truth Table

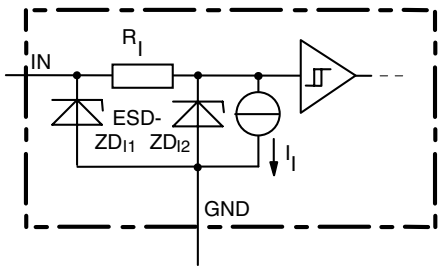
	Input-level	Output level	Status		
			432 D2	**432 E2/F2**	432 I2
Normal operation	**L** **H**	**L** **H**	H H	**H** **H**	H H
Open load	**L** **H**	[12] **H**	H L	**H** **L**	L H
Short circuit to GND	**L** **H**	**L** **L**	H L	**H** **L**	H L
Short circuit to V_{bb}	**L** **H**	**H** **H**	H H (L^{13})	**H** **H (L^{13})**	L H
Overtem-perature	**L** **H**	**L** **L**	L L	**L** **L**	L L
Under-voltage	**L** **H**	**L** **L**	L^{14} L^{14}	**H** **H**	L^{14} L^{14}
Overvoltage	**L** **H**	**L** **L**	L L	**H** **H**	L L

L = "Low" Level
H = "High" Level

Terms

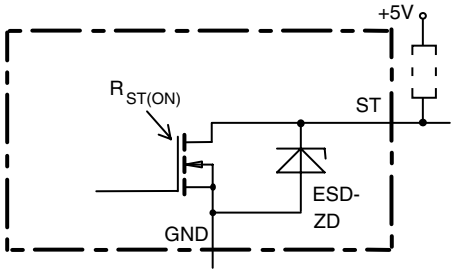


Input circuit (ESD protection)



ZD_{I1} 6.1 V typ., ESD zener diodes are not designed for continuous current

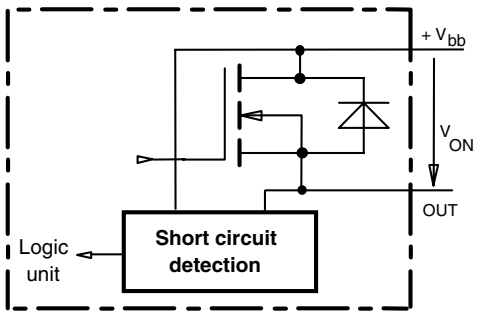
Status output



ESD-Zener diode: 6.1 V typ., max 5 mA;
$R_{ST(ON)}$ < 250 Ω at 1.6 mA, ESD zener diodes are not designed for continuous current

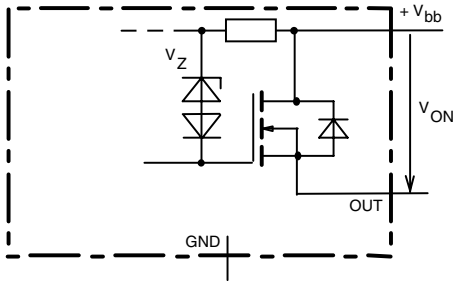
Short Circuit detection

Fault Condition: V_{ON} > 8.3 V typ.; IN high



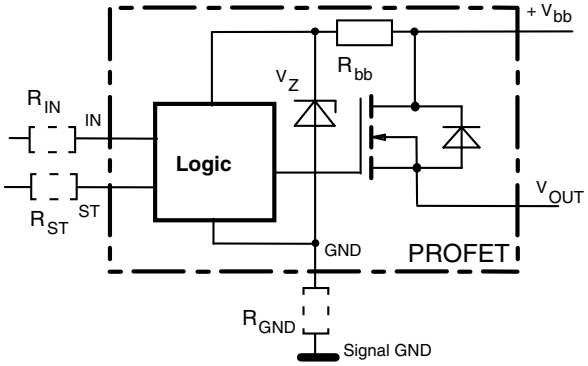
[12] Power Transistor off, high impedance
[13] Low resistance short V_{bb} to output may be detected by no-load-detection
[14] No current sink capability during undervoltage shutdown

Inductive and overvoltage output clamp



V_{ON} clamped to 58 V typ.

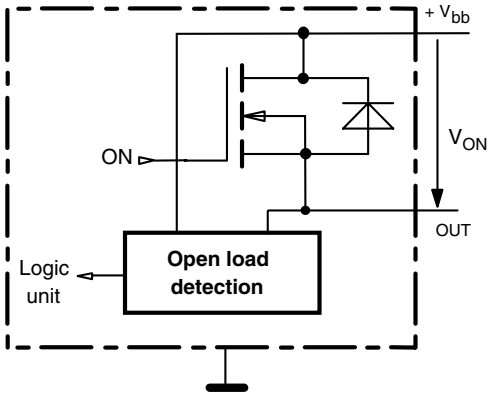
Overvolt. and reverse batt. protection



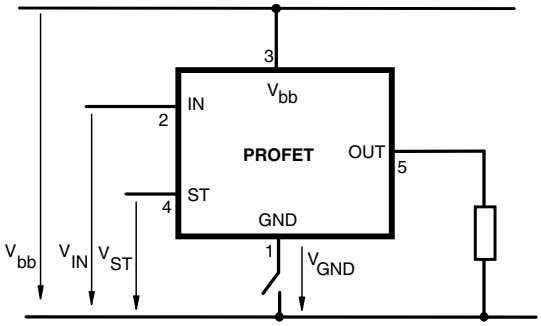
R_{bb} = 120 Ω typ., V_Z +R_{bb}*40 mA = 67 V typ., add R_{GND}, R_{IN}, R_{ST} for extended protection

Open-load detection

ON-state diagnostic condition: $V_{ON} < R_{ON} * I_{L(OL)}$; IN high

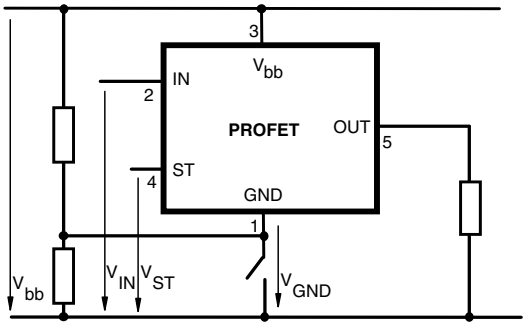


GND disconnect



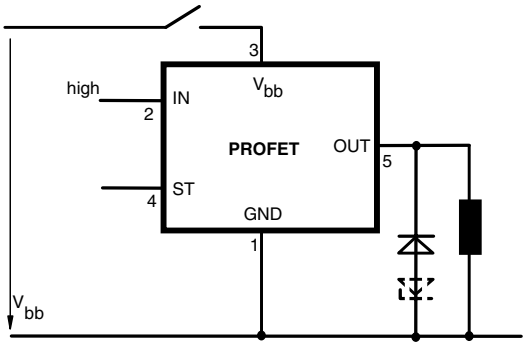
Any kind of load. In case of Input=high is $V_{OUT} \approx V_{IN} - V_{IN(T+)}$. Due to V_{GND} >0, no V_{ST} = low signal available.

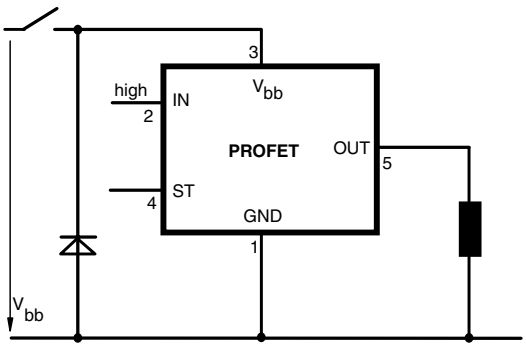
GND disconnect with GND pull up



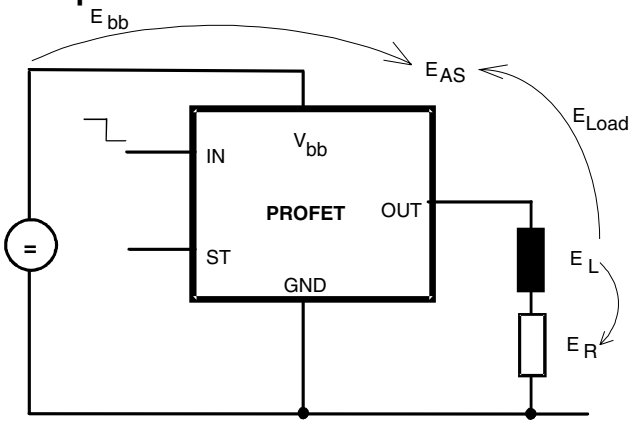
Any kind of load. If $V_{GND} > V_{IN} - V_{IN(T+)}$ device stays off
Due to V_{GND} >0, no V_{ST} = low signal available.

V_{bb} disconnect with charged inductive load





Inductive Load switch-off energy dissipation



Energy dissipated in PROFET $E_{AS} = E_{bb} + E_L - E_R$.

$E_{Load} < E_L$, $E_L = {}^1/_2 * L * I_L^2$

Options Overview

all versions: High-side switch, Input protection, ESD protection, load dump and reverse battery protection , protection against loss of ground

Type BTS	432D2	432E2	**432F2**	432I2
Logic version	D	E	**F**	I
Overtemperature protection				
T_j >150 °C, latch function[15)16)]	X		**X**	X
T_j >150 °C, with auto-restart on cooling		X		
Short-circuit to GND protection				
switches off when V_{ON}>8.3 V typ.[15)] (when first turned on after approx. 200 µs)	X	X	**X**	X
Open load detection				
in OFF-state with sensing current 30 µA typ.				X
in ON-state with sensing voltage drop across power transistor	X	X	**X**	
Undervoltage shutdown with auto restart	X	X	**X**	X
Overvoltage shutdown with auto restart	X	X	**X**	X
Status feedback for				
overtemperature	X	X	**X**	X
short circuit to GND	X	X	**X**	X
short to V_{bb}	-[17)]	-[17)]	-[17)]	X
open load	X	X	**X**	X
undervoltage	X	-	**-**	X
overvoltage	X	-	**-**	X
Status output type				
CMOS	X			X
Open drain		X	**X**	
Output negative voltage transient limit (fast inductive load switch off)				
to V_{bb} - $V_{ON(CL)}$	X	X	**X**	X
Load current limit				
high level (can handle loads with high inrush currents)	X	X		
medium level				X
low level (better protection of application)			**X**	

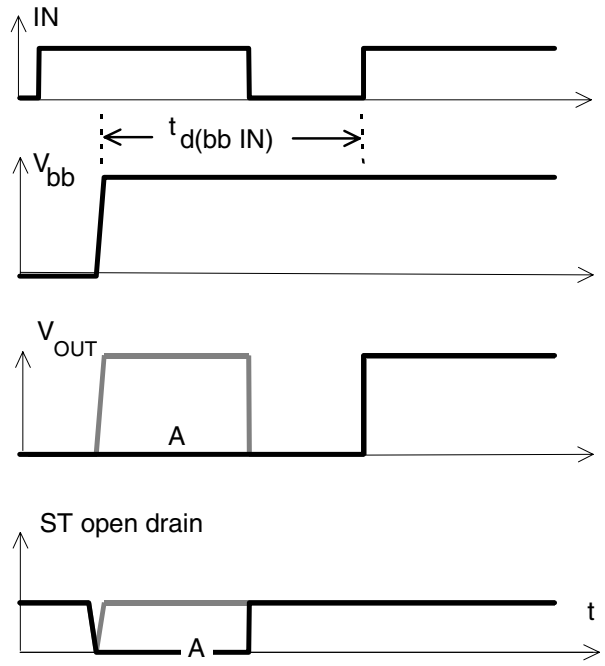
15) Latch except when V_{bb} - V_{OUT} < $V_{ON(SC)}$ after shutdown. In most cases V_{OUT} = 0 V after shutdown ($V_{OUT} \neq$ 0 V only if forced externally). So the device remains latched unless $V_{bb} < V_{ON(SC)}$ (see page 4). No latch between turn on and $t_{d(SC)}$.

16) With latch function. Reseted by a) Input low, b) Undervoltage, c) Overvoltage

17) Low resistance short V_{bb} to output may be detected by no-load-detection

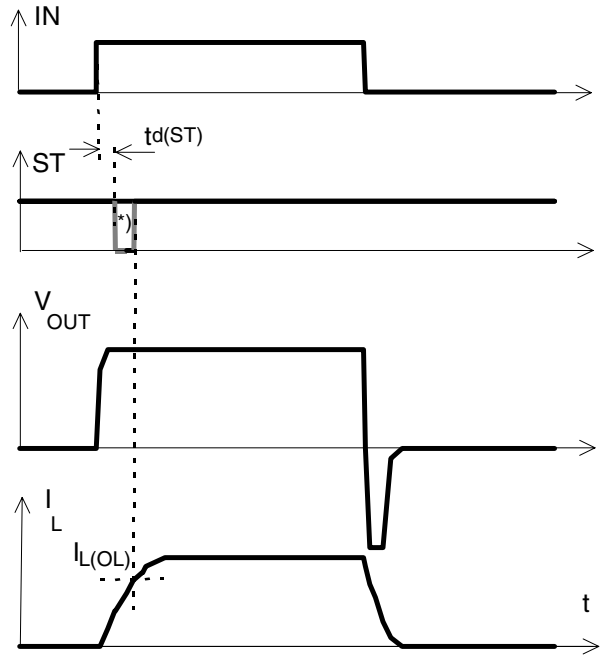
Timing diagrams

Figure 1a: V_{bb} turn on:



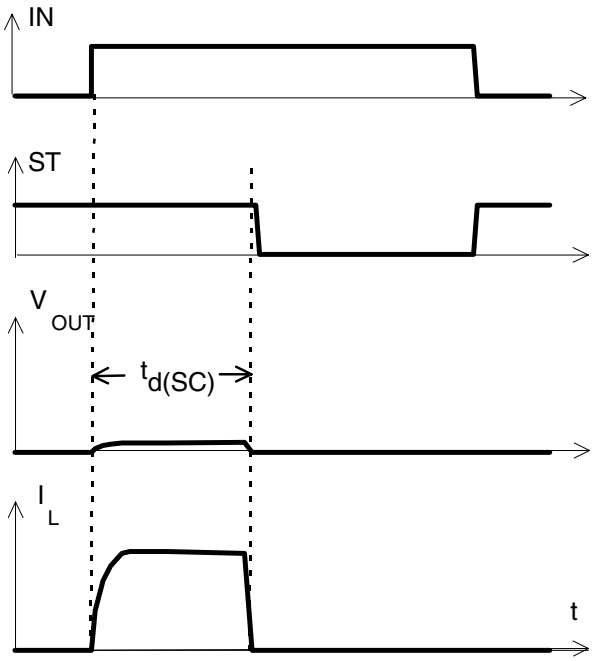
in case of too early V_{IN}=high the device may not turn on (curve A)
$t_{d(bb\ IN)}$ approx. 150 µs

Figure 2a: Switching an inductive load



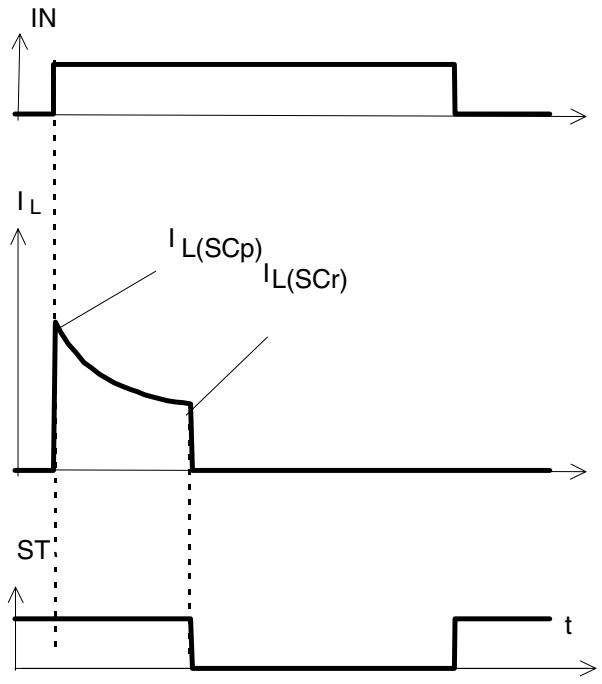
*) if the time constant of load is too large, open-load-status may occur

Figure 3a: Turn on into short circuit,



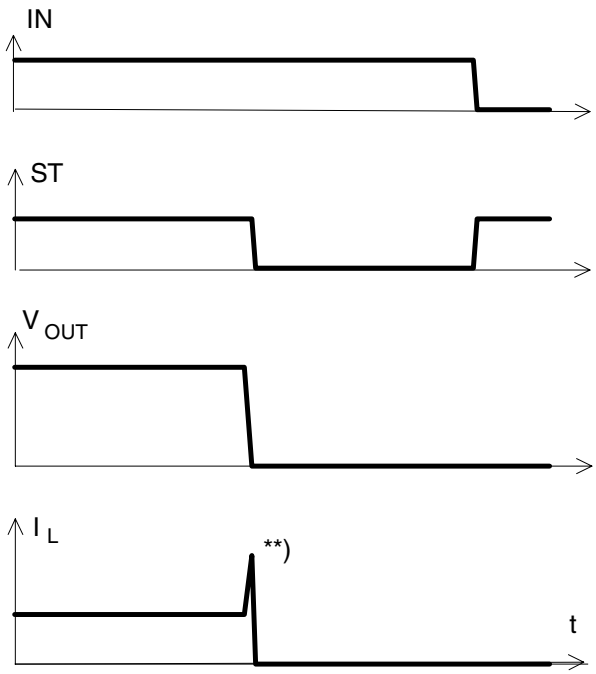
$t_{d(SC)}$ approx. 200µs if V_{bb} - V_{OUT} > 8.3 V typ.

Figure 3b: Turn on into overload,



Heating up may require several milliseconds , V_{bb} - V_{OUT} < 8.3 V typ.

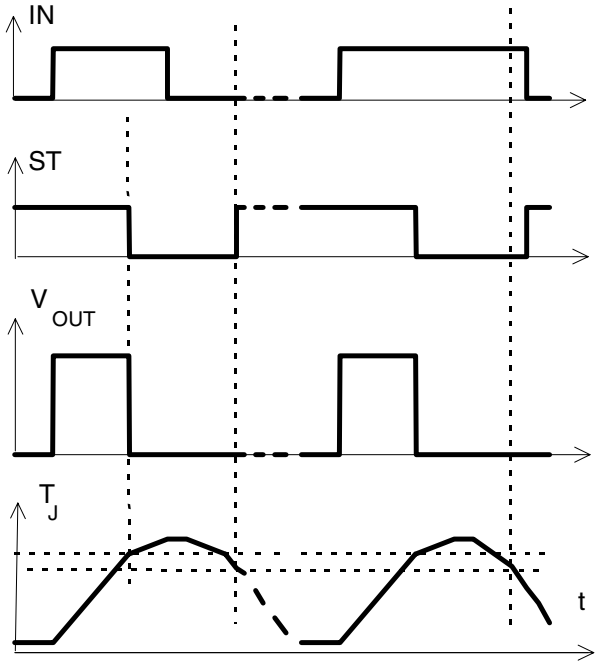
Figure 3c: Short circuit while on:



**) current peak approx. 20 µs

Figure 4a: Overtemperature,

Reset if (IN=low) and (T_j<T_{jt})



*) ST goes high , when V_{IN}=low **and** T_j<T_{jt}

Figure 5a: Open load: detection in ON-state, turn on/off to open load

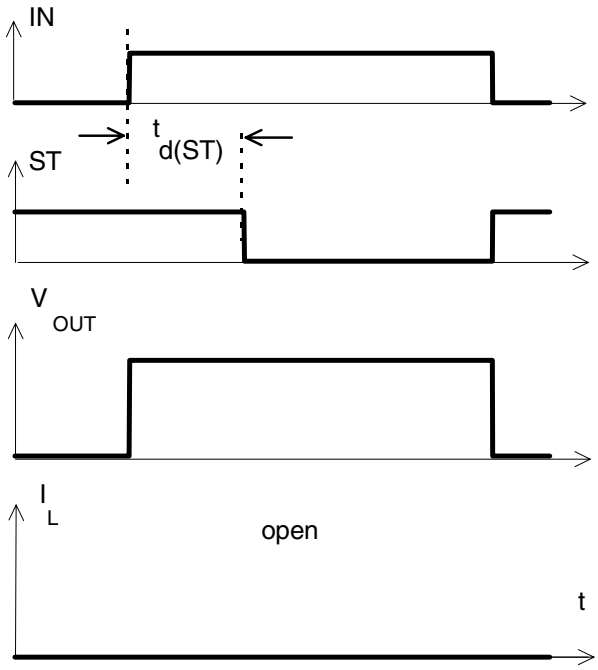
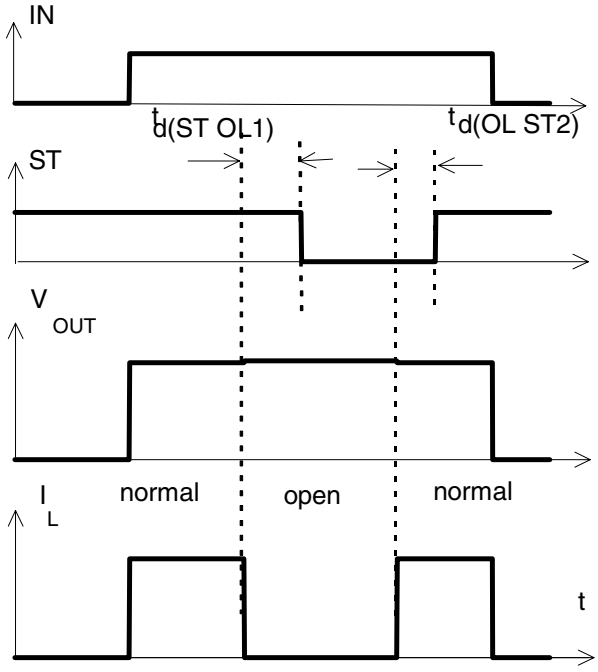


Figure 5b: Open load: detection in ON-state, open load occurs in on-state



$t_{d(ST\ OL1)}$ = tbd µs typ., $t_{d(ST\ OL2)}$ = tbd µs typ

Figure 6a: Undervoltage:

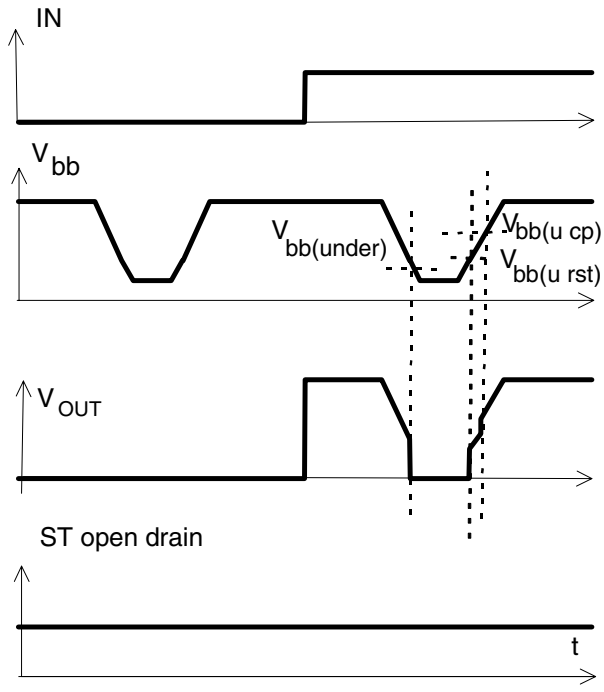


Figure 7a: Overvoltage:

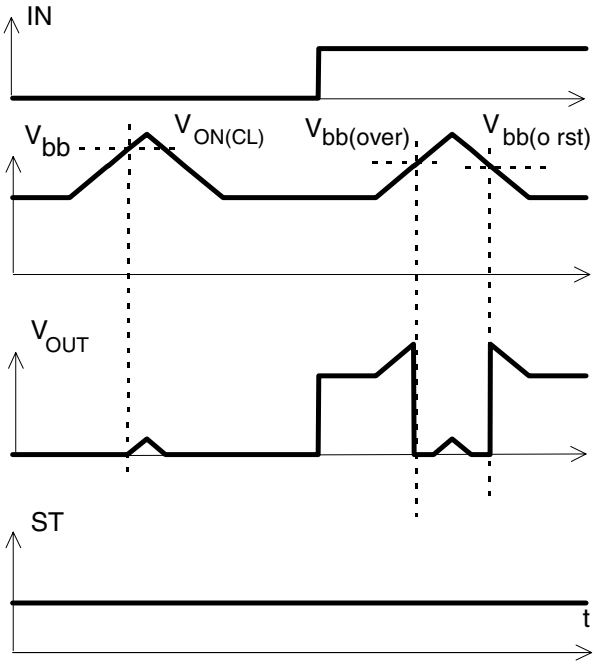
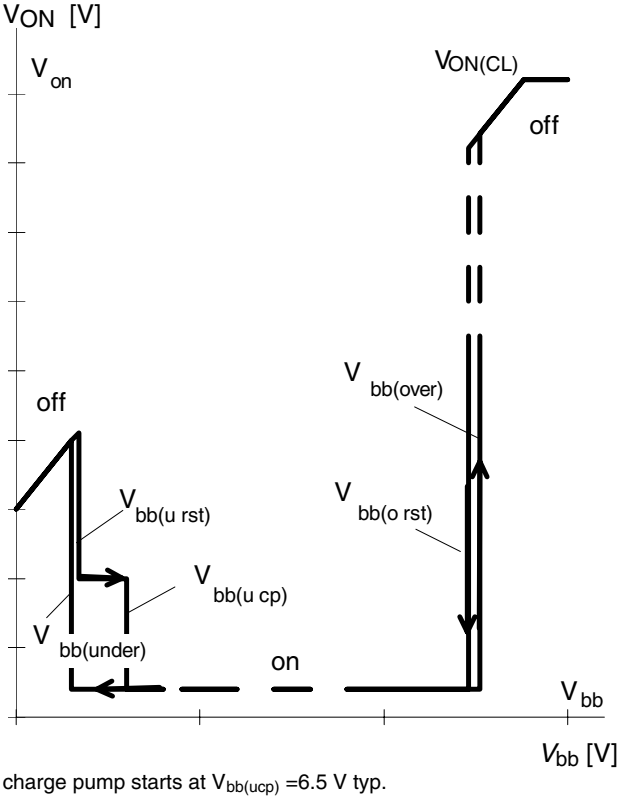


Figure 6b: Undervoltage restart of charge pump



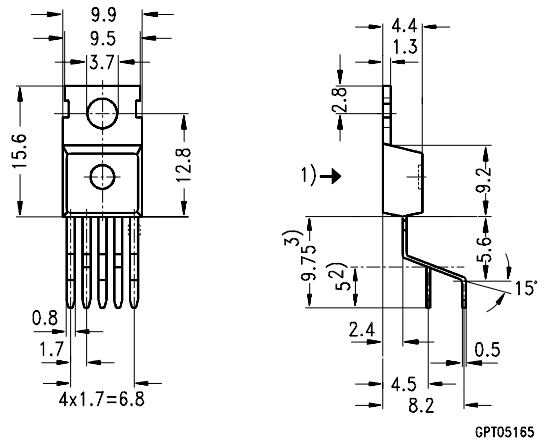
charge pump starts at $V_{bb(ucp)}$ =6.5 V typ.

Package and Ordering Code

All dimensions in mm

Standard TO-220AB/5 Ordering code

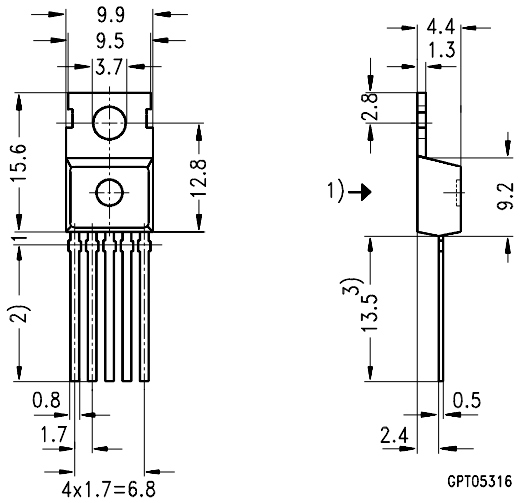
BTS 432 F2	Q67060-S6203-A2



1) shear and punch direction no burrs this surface
2) min. length by tinning
3) max. 11 mm allowable by tinning

TO-220AB/5, Option E3043 Ordering code

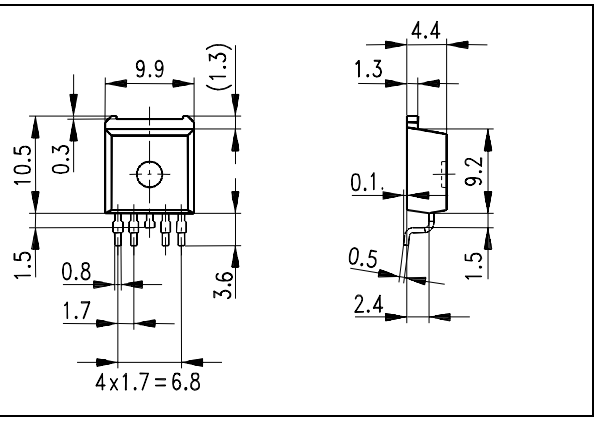
BTS 432 F2 E3043	Q67060-S6203-A4



1) punch direction, burr max. 0.04
2) dip tinning
3) max. 14.5 by dip tinning press burr max. 0.05

SMD TO-220AB/5, Opt. E3062 Ordering code

BTS432F2 E3062A	T&R: Q67060-S6203-A6



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